N

July 30, 2001

Dear: Mr. Al Lakosky
Ms. Michalle Robillard

Following is the results of my evaluation of 3 different designs of signal light systems which includes the sample supplied by Sno Glow. Please review, if you would like to discuss this further you may contact me at (218) 681-9799, ext. 3302.

Sincerely,

Fred H Bernier

Fred Bernier

Durability:

I installed the Sno Glow flasher system on a 2001 Panther 4-stroke unit. During installation it should be noted that the wires running to the rear lamp had to be lengthened. During the course of the winter 4300 miles were accumulated on this snowmobile with the flasher system installed. The flasher system remained functional throughout the accumulated miles. Durability of the system appears adequate provided care is used during installation.

Performance & Function:

Tested performance of system is various conditions, i.e. clear, blowing snow, lake, trails, fog, etc.

Best performance was noted for clear and lake conditions. Visibility up to 1 miles if there were minimal competing light sources. Blowing snow and fog offered the least performance. It appears any form of interference diminishes the performance greatly. With any interferences the side visibility is virtually nonexistent. In addition, if you approach the snowmobile from the rear on a winding trail, the reflex of the taillamp in the approaching machines headlamp completely dominates the flashing characteristics of the system and you do not perceive any flashing warning at all.

Test 2 other systems, these were remote strobe type signal lights.

One was a single directional which clipped to the windshield. It performed as well or better than the previous system by virtue of its higher position on the snowmobile itself. The drawback was it was very directional and could only be seen from 1 approach direction.

The second system was a 360° visibility amber strobe light which also clips to the windshield. From a stand point of pure visibility in all conditions, this system was superior in all tests, by virtue of 360° visibility, and its higher location on the vehicle. Also, the color was not diluted by approaching lights.

Drawbacks to this light as well as the single directional lights, could be lost, could be removed by a passerby. Additional benefits, could be located remotely in a tree or high pile of now in the event your snowmobile is not in a visible area. Also, could be carried by individual walking out on a busy snowmobile trail or along the highway.

I would be happy to discuss my findings and observations with you further if you desire.

Evaluation of:

* Sno Glow Flasher system

* Single Directional Strobe Light

* 360° Directional Strobe Light

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VISIBILITY AND JUDGMENT IN CAR-TRUCK NIGHT ACCIDENTS

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ABSTRACT

Studies of accident reports have shown that rear-end collisions of cars into trucks are more likely to occur at night and in rural settings. It is difficult to demonstrate, however, that an enhanced visibility or conspicuity of trucks results in a substantial reduction in accident rates. Several lines of reasoning may account for this disappointing conclusion, and may offer guidelines for future safety efforts. One observation is that perceptual factors do not play a primary role in all accidents. In addition, to the extent that critical decisions are based on the visual angle subtended by the visible portion of the vehicle, conspicuity enhancements may offer no useful information that is not already provided by taillights or adjacent retroreflectors at the outer edge of the vehicle.

INTRODUCTION

Roughly half of all accidental deaths in the United States involve motor vehicles. These include more than 4,000 fatalities that involve heavy trucks (gross vehicle weight over 5 tons). Although heavy trucks represent only about 4% of the total registered vehicles, they account for approximately 7% of total vehicle miles, and correspondingly make up nearly 8% of the vehicles involved in fatal motor vehicle accidents (National Safety Council, 1993). The victims of these accidents with large trucks, however, are disproportionately *not* occupants of the trucks: 77% were occupants of other vehicles, and 9% were pedestrians and other non-occupants, leaving only 14% of the fatalities as occupants of the trucks. Thus, the fatality risk associated with large trucks is primarily faced by those who strike or are struck by the trucks, and it is particularly serious in rural, nighttime situations.

A car striking the rear of a large truck is one category of collision that has received considerable attention. Many believe that car-into-truck accidents occur because the car driver does not see the truck soon enough to take adequate evasive action. This is, at first glance, puzzling because a truck with normal taillights is, partly because of its size, at least as visible or conspicuous from behind at night as a car. However, trucks (and cars) often travel below the speed of following cars in certain circumstances (e.g., on upgrades). And, such accidents are often very serious because of high closing speeds and underrides. After decades of study, the National Highway Traffic Safety Administration (NHTSA) adopted a requirement for the installation of retroreflective materials on the rear (and sides) of large trucks (80 inches wide or more, GVWR > 10,000 lbs) in order to increase their conspicuity (NHTSA, 1992).

The argument for truck conspicuity enhancement has several components and assumptions: first, a substantial number of accidents are related to poor conspicuity of trucks; second, conspicuity can be enhanced with retroreflective materials; and third, conspicuity enhancement can be shown to prevent accidents. Each of these claims needs qualification, however. The research related to truck conspicuity has been reviewed before (e.g., Sivak, 1979; Henderson, Ziedman, Burger, & Cavey, 1983; Olson, 1987) and will not be repeated exhaustively here. Instead, the purpose of this paper is to examine the evidence in terms of these critical assumptions and findings, and to describe a tool for the analysis of perceptual factors in this type of accident.

CONSPICUITY AND CAR-TRUCK ACCIDENTS

Several lines of thinking have led to the *interpretation* that nighttime truck accident patterns are an indication of conspicuity problems. Fatal car-truck accidents in general are more frequent at night (Campbell et al., 1988; Minahan & O'Day, 1977), as are both fatal and non-fatal car-to-truck-rear accidents in particular (Andreassend, 1976; Kubacki, 1979; Mortimer et al., 1974; Olson et al., 1992). Such findings are not always consistent with the conspicuity hypothesis, however. Some car-to-truck-rear scenarios are not over-represented at night (Andreassend 1976), and car-to-truck-rear accidents are not always over-represented at night compared to car-car collisions (Kubacki, 1979). Furthermore, analyses of the risk (per mile traveled) of being struck in the side or rear compared to the risk of other accident scenarios reveal that conspicuity is a greater problem for flatbed trailers than for other truck-trailer configurations such as vans or tanks (Olson et al., 1992). The following conclusion has been made: "*Since car-into-tractor-semitrailer collisions at night are* over-represented, making trucks and semitrailers more conspicuous through addition of lights or reflective *paints should reduce the frequency of such accidents*" (Kubacki, 1979, p. 6; similar suggestions have been made by many others, including Andreassend, 1976; Minahan & O'Day, 1977, 1979; Sivak, 1979).

Despite its plausibility, this argument is not compelling. Alternative explanations, giving visibility problems a less central role, are available for the over-representation of car-into-truck-rear accidents at night. Relevant factors include alcohol, sleepiness, and fatigue from long driving (Henderson, Ziedman, Burger & Cavey, 1983). For example, trucks traveling more slowly than cars at night would be likely targets for rear impact by drivers who are drunk or falling asleep.

There is also disagreement on which accident scenarios are candidates for conspicuity enhancement. Although the emphasis here is on night accidents, it is frequently suggested that conspicuity enhancement could prevent side and rear impacts into trucks during the daytime as well. Indeed, accidents treated as *potentially relevant in conspicuity analyses* have included all accidents involving a truck struck by another vehicle (Burger et al., 1985) or with some constraints on direction of travel (Olson et al., 1992). Thus, night/day comparisons for car-into-truck-rear accidents vs. other scenarios are definitive with respect to neither the importance of conspicuity nor the impact of its enhancement.

Indeed, the role of conspicuity problems in accidents may be quite limited. The Indiana Tri-Level study involved on-site investigations of over 2,200 accidents. Misjudgment of distance or closure rate was considered to be relevant in only 2.5% of the accidents, whereas inattention to traffic accounted for 7.1% of the accidents (Treat et al., 1977). Although some *looked-but-failed-to-see* accidents were included among the 23.1 identified with *improper lookout*, the majority of the *improper lookout* accidents involved either *failed to look*, pulling out at intersections, or both, and therefore would be irrelevant to conspicuity treatments for rear-end collisions. Additional evidence comes from a recent survey study, where self-reported frequency of errors such as misjudging gaps or failing to notice a vehicle did not significantly predict accident rate. Self-reported frequency of violations (deliberate illegal or improper driving behavior) was a significant accident predictor (Parker et al., 1995), however. Finally, a review of 497 truck accidents by the Bureau of Motor Carrier Safety (described in Burger et al., 1981) found that negligence of striking-vehicle drivers was cited in most narratives. For rear-end collisions, it was judged, 42% of these drivers were inattentive, 16% were asleep, 18% were driving too fast, and 4% were impaired by alcohol or drugs.

CONSPICUITY ENHANCEMENT

One must distinguish between the concept of conspicuity and specific operational definitions such as the detection distance for an approaching vehicle. *According to* Sivak (1979), "*Conspicuity is the* property of a peripherally located object that is likely to lead to the object's detection and subsequent foveal fixation (and identification) by reason of its size, luminance, contrast, or other physical properties" [p. 10]. Similarly, Henderson, Ziedman, Burger & Cavey (1983) consider that conspicuity includes "not only that attribute of a vehicle that calls attention to itself as a stimulus, but also those attributes that contribute to the recognition of a stimulus as a vehicle and the general understanding of what the vehicle is doing relative to the observer" [p. 2]. As Burger et al (1981) note, the distance at which an alert driver can detect or correctly interpret a stimulus is not the key issue in accident prevention, "but rather the characteristics about a stimulus that enables a driver to detect it in an inattentive state" [p. 4-30].

Consider, therefore, this summary of car-into-truck accidents from Burger et al. (1981, p. 3-37):

"*Rear impacts tend to occur when the truck is* traveling straight ahead and moving slowly, stopping or stopped on the roadway. The following driver either (1) does not see the truck at all, (2) sees the truck but misjudges its motion and/or distance or (3) correctly perceives the truck's dynamics and distance too late."

If a failure to see or decide in time is central to car-into-truck-rear accidents, and if conspicuity involves those characteristics that can alert an inattentive driver, then conspicuity enhancement should prevent virtually all such accidents (not to mention side and other impacts into trucks). In practice, however, research on the conspicuity enhancement of trucks has focused on increasing the information available at a greater distance.

The detectability distance of trucks at night clearly depends on various stimulus properties such as taillight luminance (Henderson, Sivak, Olson & Elliot, 1983) or the size and reflectivity of retroreflectors in the absence of taillights (Olson et al., 1992). Increases in detectability distance, however, may have limited practical significance, since the availability of taillights alone permits detection long before driver action is necessary to avoid a slowed or stopped truck (Henderson, Ziedman, Burger & Casey, 1983). Except for car-into-truck-rear accidents involving trucks stopped without any lights on at night, conspicuity enhancement is unlikely to provide any substantial benefits merely by affecting truck detectability.

A general consideration of visual problems for night driving leads to the same conclusion. Under night illumination, the differences in functioning of the two visual systems under degraded lighting is critical. For example, the ambient visual system (both peripheral and central in locus), which is responsible mainly for signaling about the individual's location with respect to the environment, shows relatively little degradation as the lighting conditions are reduced. The focal visual system, which is responsible for identification and detection of objects in central vision, however, is severely degraded by reduced illumination. Consequently, drivers (operating with ambient visual system for guidance at night) tend to overdrive their headlights, failing to reduce speed from what is appropriate in the daytime despite a decrease in the ability to extract detailed information from the scene ahead (Liebowitz et al., 1982). Combined with night myopia (inappropriately close focus) for many drivers, such visual impairment makes it difficult to see poorly lit stimuli such as pedestrians, cyclists, and disabled vehicles (Liebowitz & Owens, 1977). Thus, car-into-truck-rear accidents where the truck is stopped without lights at night would be the main targets for conspicuity enhancement.

ACCIDENT PREVENTION

Two types of accident studies address the use of retroreflectors in preventing car-into-truck-rear accidents. One type deals with the effects of retroreflective license plates. Although these studies have used data for cars rather than trucks, they are restricted to nighttime rear impacts. Comparisons of accident rates with and without reflectorized license plates (either before or after installation, or for different groups with/without plates) have provided mixed results. Reviewers have noted methodological problems in most of the studies, and have either concluded that retroreflectorized license plates provide some benefit or that the issue is not settled (see Henderson, Ziedman, Burger & Casey, 1983; Cook, 1975; Olson & Post, 1977). Several of the studies suggested that the principal benefits occur for cars parked at night. As Olson & Post noted, a retroreflective license plate is unlikely to improve the odds that a car will be seen if its taillights are on (without substantial dirt accumulation or other problems), nor is it likely to aid in judgment of separation distance.

In summing up the work on retroreflective license plates, Olson and Post observed, "In general, the studies which had the more rigorous experimental controls report the smallest differences". The same could be said for accident reduction associated with retroreflective markings on trucks. NHTSA provides several dramatic accounts of accident reductions following conspicuity enhancement, as reported by commenters on its proposed rulemaking (NHTSA, 1992) without any details on data collection and analysis methods. An early study involving Greyhound buses has been referred to as showing a significant reduction of struck buses (Henderson, Ziedman, Burger & Cavey, 1983), although the actual reduction in miles per collision accident was apparently less than 1% (data cited in Sivak, 1979). The U. S. Post Office Department reported less than half as many rear-end accidents for vehicles painted red (reflectorized), white and blue as compared with an equal number of olive-drab vehicles. Any effect, however, could be attributed at least in part to the color change rather than the retroreflective material (Sivak, 1979).

The first reasonably controlled study of the effectiveness of retroreflective materials involved a comparison of accident rates in England for trucks over 3 tons unladen weight before and after the effective date that rear markings were required. The markings included fluorescent materials to enhance conspicuity in day and lit conditions, and retroreflective material for unlit night conditions, and nearly 35,000 accidents were considered (Transport and Road Research Laboratory, 1976). Among the conditions examined, the only one for which the reduction of rear impacts was significantly greater than the other impacts was parked trucks on dark, unlit rural roads. Further examination shows that for non-parked trucks there was no advantage of rear vs. other impacts with respect to accident reduction. This pattern matches the findings from license plate studies: rear retroreflective markings are most helpful for a vehicle that is otherwise unlit (dark conditions and no taillights). It is also noteworthy that the reduction in all rear impacts associated with conspicuity enhancements was under 5%, and was unlikely (at a .05 confidence level) to have exceeded 6% for two-vehicle injury accidents involving rear damage to trucks.

The most ambitious study to date is the field evaluation conducted under NHTSA contract (Burger et al., 1985). Over 200 million miles of exposure were accumulated, divided between reflectorized and control portions of two truck (van) fleets. Out of 612 on-road accidents reported, 45% were considered to be conspicuity-relevant (truck-struck). There were 15.2% fewer conspicuity-relevant accidents in the reflectorized than in the control set ($p = .09$), with the difference somewhat greater for night than for day accidents. The conspicuity-relevant accidents were divided into high, medium, and low relevance by raters (criteria not reported). Oddly, the reflectorized advantage was greater for the low-rated than for the medium-rated accidents, although the largest difference was for the small set of high-rated accidents. The result of this study was a marginal finding of a 7% overall reduction in truck accidents, and NHTSA (1992) was unwilling to assume a daytime benefit due to the enhancement of retroreflective conspicuity.

It is too soon to perform a definitive evaluation of the effectiveness NHTSA's conspicuity requirement, which had an effective date of December 1, 1993. At the time of writing, truck accident data for 1994 is not yet available. An exploratory analysis, however, can be based on the assumption that truck fleets were phasing in the conspicuity enhancements in the months and years leading up to the requirement, as indicated by comments to the rule. An examination of data from FARS (NHTSA's Fatal Accident Reporting System) reveals that fatal accidents involving heavy trucks struck in the rear have been increasing as a percentage of all heavy truck accidents since 1975. In fact, the highest percentage yet was for 1993, the most recent year for which data is publicly available.

Thus, despite the plausibility of the conspicuity enhancement argument for car-into-truck-rear accidents, the accident record has demonstrated only small benefits at best. Although a 5-15% reduction would be desirable and may well be cost-effective, it unfortunately leaves the majority of the accidents unaffected. To comprehend why conspicuity enhancement based on retroreflectors produces such small benefits, the perceptual bases of nighttime visibility in such situations need to be re-examined.

CRITICAL INFORMATION

Burger et al. (1981) analyzed a large number of vehicle-into-truck accident reports and developed a set of common scenarios. From these, they identified a variety of visual information needs for the drivers of other vehicles; crucial among these are information about the distance and speed of the truck (including whether it has slowed or stopped). They also noted two major problems with the transmission of such information: poor attention or alertness, and the difficulty of judging speed and distance.

To avoid a car-into-truck-rear accident with a slow or stopped truck, an approaching driver must recognize not only that a vehicle is ahead, but also that a collision is imminent. The first task is reasonably simple, as taillights can be detected (by alert drivers, at least) at distances far beyond the minimum required for avoidance (Burger et al., 1981). More difficult to judge is the speed of closure. There are several sources of visual information that drivers can rely on. They involve aspects of the visual angles subtended by the lead vehicle at the distance of the following vehicle.

Information about the status of a vehicle ahead can be based on the fact that the visual information from the vehicle "sweeps across" the immediate and adjacent background, and particularly so if the lead vehicle is moving on a curved roadway. Such information, unfortunately, is often largely unavailable at night due to lack of background illumination, especially in rural settings. Therefore, to determine the speed of the forward vehicle at night, the driver depends on two additional cues based on the visual angle subtended by the leading vehicle.

Rate of Visual Expansion

One important cue is the rate of change of the visual angle. If the driver detects that this angle is increasing, this provides information that the driver is approaching the object ahead. The rate of expansion and the optical size of the object are usually combined to define the optical variable *Tau*, which is proportional to time-to-contact. Here, *Tau* is the reciprocal of the proportionate rate of expansion, which is given by the rate of change of the visual angle divided by its momentary visual angle (see Lee, 1976; Lee & Young, 1974; or Schmidt, 1988).

Tau and the rate of expansion of the visual array have provided useful understanding of how we detect that objects are approaching. Unfortunately, when a stationary (or barely moving) object the size of a car is several hundred feet ahead of a following vehicle, the lead vehicle's visual angle does not expand rapidly enough (even if approached at 60 mph). Observers therefore have difficulty in detecting whether or not the rate of expansion is greater than zero. The threshold for detecting the expansion of the visual array has been estimated at about .0035 radians/second (0.2 degrees/second) by various methods (see Mortimer, 1990).

The relevance of this information for detecting the status of the forward vehicle can be seen in Figure 1. We assumed that a conspicuous 6-ft object (with visible taillights or reflectors) is stopped on the roadway at night, and another vehicle is traveling 60 mph behind it. Figure 1 shows the rate of change of the lead vehicle's visual angle (as seen by the driver behind) as a function of the distance between the vehicles. Notice that when this distance is greater than 400 ft., approximately, the rate of change of the visual angle remains very low (0.1 degrees/second or less), and below the nominal threshold of 0.2 degrees/second. In this example, the threshold is

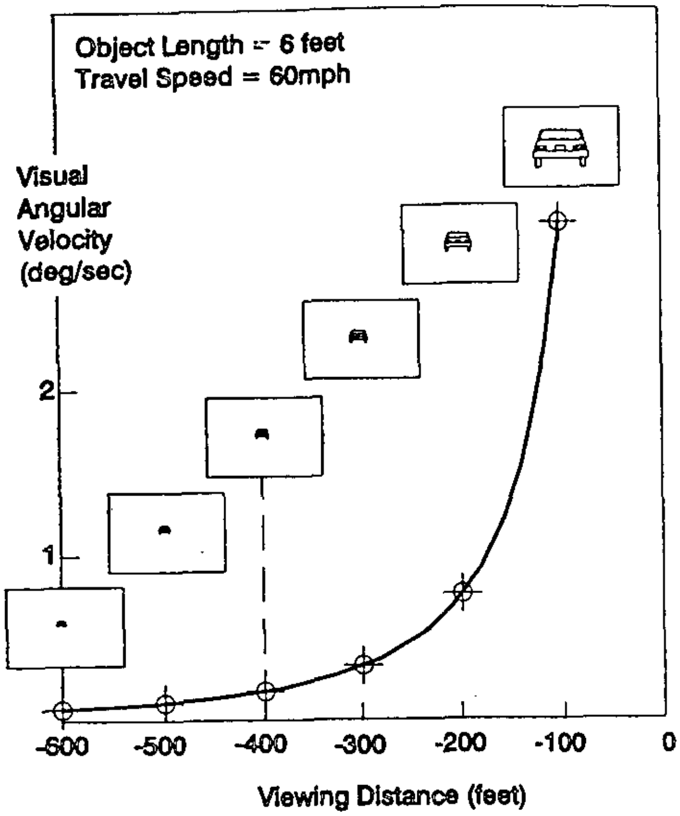

Figure 1. Rate of change of visual angle.

exceeded when the vehicles are separated by only 387 ft. Assuming a 1.5-second driver reaction time plus the stopping distance associated with a locked-wheel skid, the stopping distance is about 300 ft. Therefore, if the object is detected only by cues based on the rate of visual expansion, the driver is approaching the limits of his/her capability to avoid a collision.

An important implication of the above argument is that a stopped vehicle's conspicuity alone contributes little to the driver's ability to avoid a rear-end collision. They can usually see the vehicle at a distance far greater than the braking distance. Perhaps this explains why, as we mentioned earlier here, enhancing the vehicle's conspicuity by lighting or reflectorization has such a negligible effect in these accidents. *Seeing* the vehicle is not the problem; recognizing that it has stopped is the crucial issue.

We have combined several of the relevant variables of this detection process into a simple mathematical model. These variables are (1) the size of the stopped object ahead, (2) the speed of the approaching vehicle, (3) the threshold for detection of visual expansion, (4) reaction time to initiate braking once the expansion is detected, and (5) the coefficient of friction that determines the distance and duration of a

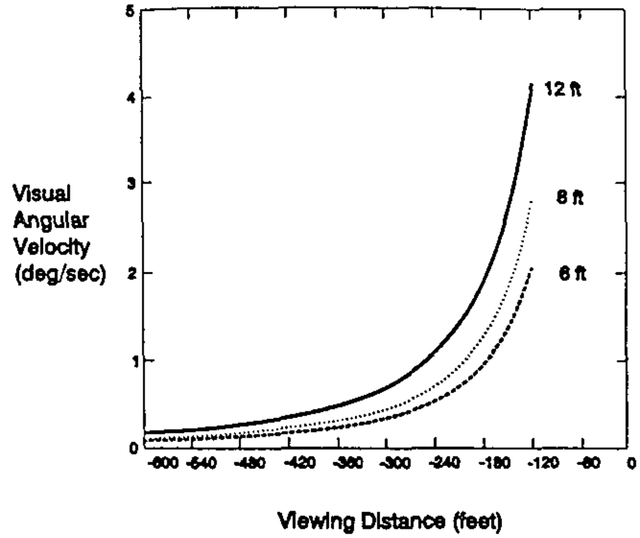

Figure 2. Rate of visual angle change at 60 mph: effect of target width.

locked-wheel skid. Basic features of the problem emerge by manipulating several of these variables.

Object Size. An object's size is an important factor when detecting relative motion. With larger objects, the rate of visual expansion will be greater at any given distance, since the object's visual size and its rate of expansion are proportional regardless of speed. This is shown in Figure 2, where we have plotted the rate of visual expansion as a function of three different vehicle sizes: 6, 8, and 12 ft. Notice that as the object's size increases, the curves shift upward. Therefore, the object exceeds the nominal threshold for detecting visual expansion when the follower is systematically farther away. In the example here, the 6-ft. vehicle is detected when the distance is about 400 ft., whereas the 12 ft. vehicle is detected at about 540 ft., providing additional time and distance to avoid collision.

This conclusion has significant implications for various nighttime collisions. Objects whose sizes are relatively small, such as stray objects, motorcycles, and even small vehicles are especially dangerous when approached at a high speed, since the threshold of the rate of visual expansion will be exceeded only when the following vehicle cannot avoid striking it. Thus, for earliest detection, the visual angle subtended by the lead vehicle should be as large as possible, which maximizes the rate of visual angle change with decreasing headway. This means that taillights should be placed as far apart as vehicle width allows (Fisher & Hall, 1978; Janssen et al., 1976; Mortimer, 1988). Conspicuity enhancement, in the form of

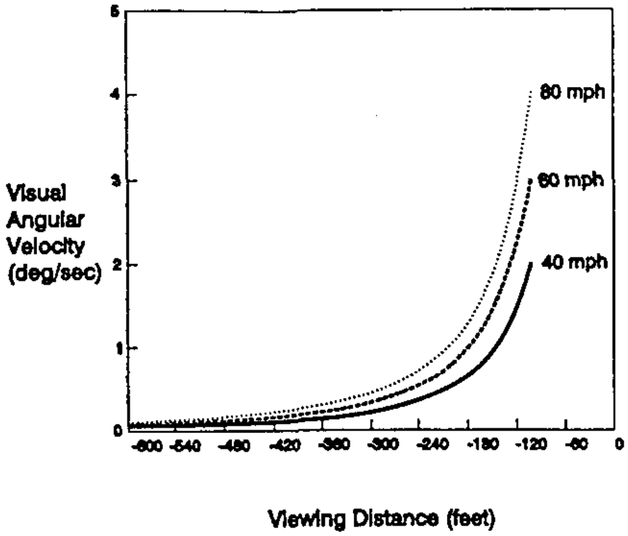

Figure 3. Rate of visual angle change with a 6-foot target: effect of approach speed.

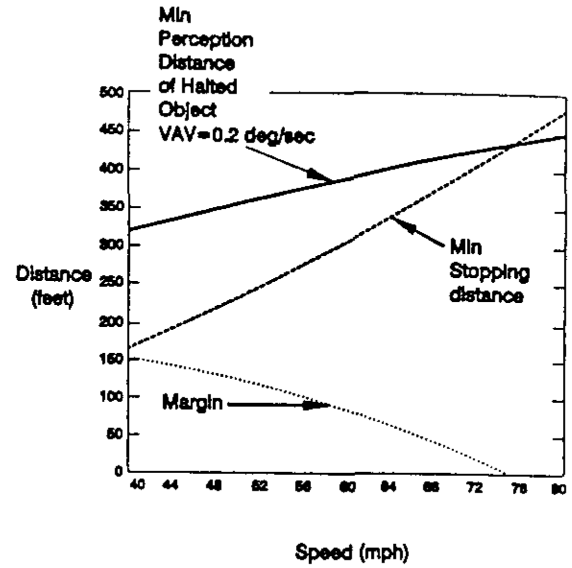

Figure 4. Minimum perception distance and minimum stopping distance as a function of approach speed. (Assumptions: coefficient of friction = 0.7, reaction time = 1.5 seconds, threshold = 0.2 degrees/second).

retroreflectors on the rear of a truck, is unlikely to help a truck that has slowed or stopped with its lights still on at night, because this contributes to neither the reasonable visibility of the image nor to its size (although there may be a small benefit from adding the upper corners of the truck, perhaps because the diagonal is somewhat longer than the width). However, our analysis assumes that the vehicle ahead be detected as an expanding object. In the case of approaching the side of a truck, if the truck is illuminated by small lights or reflectors at the corners, it is possible that a driver will interpret them as sets of smaller objects (perhaps as part of the background), and not as belonging to the truck. This suggests that the reflecting material should ensure that the vehicle is easily viewed as a single object. Obviously, additional experiments could be conducted to test the validity of this claim.

Vehicle Speed. Another substantial factor in the driver's capability to detect a stopped vehicle in time is, of course, the following vehicle's speed. In Figure 3 we have plotted the rate of visual expansion as a function of distance again, but this time for three vehicle speeds--40, 60, and 80 mph. This produces a slightly complex picture: when the speed is increased, the rate of visual expansion essentially increases proportionally. At the same time, however, the capability to stop before colliding with the object decreases markedly. In our simulations, holding the reaction time constant at 1.5 seconds, we estimated the distance to bring the car to a stop, assuming a locked-wheel skid and a friction coefficient of 0.7. With a detection threshold of 0.2 degrees/second, the stopping distances are 164, 304, and 481 ft. for the 40-, 60-, and 80-mph conditions, respectively. We calculated that, at 40 mph, the vehicle would stop well before (153 ft.) colliding with the object. At 60 mph, the vehicle would stop just before (84 ft.) colliding with the object. But at 80 mph, the following vehicle would have collided with the stopped object at a velocity of 34 mph. Clearly, higher vehicle speeds, particularly with low-beam headlights, increase the risk of driving if vehicles ahead may be slowed or stopped.

The importance of approach speed is clear when the stopping distance and perception distance are directly compared. Figure 4 is based on assumptions of 0.7 for the coefficient of friction, 1.5 seconds for reaction time, and 0.2 degrees/second for the threshold for detecting change of visual angle; these assumptions are for illustration only, and need to be determined for any given situation of interest. In general, the margin (difference between stopping distance and perception distance) drops to zero with higher speed.

Headway Changes

A second cue is simply an increase in the magnitude of the visual angle subtended by the object, which indicates that the distance-headway has decreased. The threshold for detecting a change in distance-headway is generally found to be about 12% or larger (Hoffman & Mortimer, 1994a,b; Mortimer, 1990). In

Table 1. Time and travel distance needed for a just detectable change (12%) in headway for a driver approaching a stopped vehicle at 60 mph.

Initial headway (feet)	Time (seconds)	Distance (feet)
3000	3.65	321.4
2500	3.04	267.9
2000	2.44	214.3
1500	1.83	160.7
1000	1.22	107.1
500	0.61	53.6

other words, when the headway has decreased by about 12%, an average alert observer is just barely able to detect that the lead vehicle is apparently larger, hence closer. Some have suggested that the angular information from the roadway distance between the vehicles can also provide a similar cue, but this information would be severely degraded at night.

At longer headways, however, the approaching driver can only use change of headway as a cue that headway is decreasing. As Table 1 shows, however, the time needed for the headway change to exceed threshold is a direct function of headway-distance; at an initial headway of 1500 feet, for example, it takes 2 seconds (161 feet of travel) before the visual angle subtended by the vehicle ahead to change by a barely detectable amount. In practice, it is unlikely that the approaching driver will notice this change, because the change is so gradual. In addition, typical visual fixations are on the order of a third of a second (Finnegan & Green, 1990), except when following a car at short headway (Olson et al. 1989). So the driver probably looks away before the image of the lead vehicle has expanded perceptibly. At these longer headways, the amount of information about relative velocity that is transmitted to the approaching driver can be as low as one bit. That means that the driver only knows whether the headway is increasing or decreasing, with no knowledge of the magnitude or the velocity (Mortimer et al., 1974).

Fortunately, there is a well-known and widely-used conspicuity enhancement that can provide the approaching driver with better advance information: flashing lights. Even more salient than brake lights, flashing lights can catch attention, alert an inattentive driver, and indicate that the vehicle ahead is not proceeding normally. At the same time that rulemaking was proposed for retroreflective conspicuity treatments for trucks, research demonstrated that flashing lights were effective for warning approaching drivers of slow-moving or disabled vehicles (e.g., Lum, 1979; Knoblauch & Tobey, 1980). According to Olson (1987):

"It is important that vehicles that are stopped or moving much slower than other traffic be distinctively marked. Emergency flashers are effective for this purpose because flashing lights have great attention-getting power, and the system has come to be identified with stopped or slow-moving vehicles."

Similarly, special lighting may be useful for marking of certain classes of vehicles that are likely to be driving slowly or stopping frequently. Noting that car-into-truck-rear accidents make up a relatively large portion of accidents for garbage trucks, Mortimer et al. (1995) cite rotating yellow beacons along with fluorescent and reflective clothing for the workers as possibly beneficial.

CONCLUDING REMARKS

Retroreflective treatments have not demonstrated any substantial reduction in car-into-truck-rear impacts. Analyses of accident data suggest that perceptual problems play a decisive role in only a small portion of accidents, and that the conspicuity problem for trucks may be limited primarily to flatbed trailers. There is some indication that retroreflectors may be helpful for trucks that are parked on unlit roads at night, but they would not be anticipated to add appreciably to safety when taillights are used. Flashing lights provide an effective and reasonable means for enhancing the conspicuity of a vehicle that has slowed or stopped. Most importantly, our analyses indicate that the limiting factor in such situations seems to be the driver's capability to detect that the visual array is expanding--and hence that the truck has stopped--especially when his or her speed is elevated. Perhaps these notions provide assistance in understanding why enhancing conspicuity, per se, has had such a limited effect in reducing such accidents.

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Visibility Problems in Nighttime Driving

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ABSTRACT

Many traffic accident cases involve questions of driver visual perception. It is common for one or both sides to employ experts in such matters. These individuals often make use of reconstructions in an effort to arrive at an opinion concerning driver perception. While such reconstructions can be helpful, they can also be very misleading. The purpose of this report is to review basic information concerning visual perception, to lay a foundation for understanding how the visual system works under nighttime driving conditions. Applied research on night driving will be covered as well, with a particular focus on detecting conditions in the forward field. The report concludes with a section on problems that can degrade visual performance at night.

THE PROBLEM - Many traffic accident cases argued before juries in this country involve questions of driver visual perception, e.g., what a driver could or should have seen, when or at what distance he/she should have seen it. While preparing their case it is not unusual for one or both sides to hire experts to address this issue. The experts will sometimes prepare reconstructions of the event in an effort to estimate the values in question. On the surface, this sounds like an ideal approach. Indeed, it can sometimes be very useful. However, it has distinct limitations. For example, estimating something like nighttime detection distance for an object by measuring the distance at which one or even several persons can see it in a reconstruction is like trying to estimate the stopping distance of a large truck by using a sports car. No judge would allow the latter type of evidence to be introduced. No judge should allow the former evidence to be introduced either.

But, if one cannot estimate values such as these from a reconstruction, where are they to come from? There are two possibilities. First there are data that can be helpful, if knowledgeably employed. Second, if all else fails, reconstructions can be used. However, the investigator must understand the limitations of such an approach, so that appropriate corrections can be made to the resulting data.

This paper is intended to summarize information on the question of driver visual perception under nighttime operating conditions. The hope is that it will aid individuals involved in accident analysis and reconstruction to better understand visual perception and how its operation and limitations may affect a given situation.

ESSENTIAL STEPS IN DRIVER INFORMATION PROCESSING - Before a driver can be expected to make an appropriate response to any roadway situation four things have to happen. According to Alexander and Lunenfeld (1) these are:

1. Detection. Detection results in a conscious awareness that something is present.

2. Identification. In this step enough information is acquired about the "something" to allow the driver to make an appropriate decision as to what, if anything, to do about it. The information would typically include what the something is, and, if it is capable of movement, what it is doing. The identification need not be complete in detail. For example, a driver doesn't have to know if the object ahead is a cow, truck, or boulder; it is enough to know the lane is blocked.

3. Decision. The driver decides on a response to the condition.

4. Response. Orders are issued by the motor center of the brain to the appropriate muscle groups to initiate the response decided on.

The first two steps, detection and identification, involve perception and information processing, and will be the focus of much of this report. The key point to be made here is that detection and identification are different processes. Correct identification does not automatically follow detection, and a failure in either one can result in disaster.

Some accidents that have been attributed to a failure on the part of the driver to maintain a proper lookout were quite possibly due to misidentification. Sometimes drivers find themselves in situations that can be deceiving. For example, vehicles with unusually closely spaced headlamps may look further away than they actually are. Other situations tax the limits of the perceptual system. Examples of these will be offered later. It may not be possible to determine with certainty what happened in a specific instance, but a more complete understanding of the operation and limits of visual perception can at least aid in determining whether the statements offered by a witness are reasonable for a given set of circumstances.

DRIVER RESPONSE TIME - The steps in information process just described require time to accomplish. How much time is a question that is not only frequently raised in litigation, but is of considerable importance in roadway design as well.

The time that it takes a person to respond to a stimulus has been a subject of investigation for a long time. In the simplest of situations, i.e., fully attentive young subject, a clear stimulus, and a simple response such as pressing a button, response times of about 0.15 second will normally be obtained. As the amount of information the subject is required to process is increased, response time increases as well.

A number of studies have been concerned with the time it takes a driver to apply the brakes when confronted with some kind of stimulus. This was sometimes measured by simple tasks such as pressing the brake when a hood-mounted light came on. An early review of such data (2) concluded that brake reaction time for the majority of drivers is between 0.5 and 0.7 second.

The real question is how long does it take drivers to respond to unexpected stimuli of various types under realistic driving conditions? Such studies are very difficult to carry out because of the need for catching the subject unaware in a driving situation without causing undue risk. However, in recent years there have been some very interesting studies reported. For example, Triggs and Harris (3) observed the response times of passing motorists to a variety of conditions they had set up. Table 1 is a listing of the 85th percentile reaction times they found for the different situations. Not all the conditions have the same urgency value. For example, the Roadworks sign, in the absence of evidence of construction, would not be expected to elicit a strong response. The authors also point out that the response of drivers to

Table 1

85th Percentile Reaction Time Values

C.R.B. "Roadworks Ahead" Sign	3.0s
Protruding vehicle with tyre change	1.5s
Lit vehicle under repair at night	1.5s
Parked Police Vehicle	2.8s
Amphometer* : Beaconsfield	3.4s
Amphometer : Dandenong North	3.6s
Amphometer : Gisborne	3.6s
Amphometer : Tynong	2.54s
Railway crossing : Night (General Population)	1.50s
Railway crossing : Night (Rally drivers)	1.50s
Railway crossing : Day	2.53s
Car following	1.26s

From: Triggs and Harris, 1982.

*An amphometer is a speed-measuring device consisting of two pneumatic tubes spaced some distance apart. It is commonly used in Australia.

stimuli such as a parked police vehicle or the amphometer (a speed measuring device) depends to some degree on how fast they are going relative to the speed limit at the time of detection.

Summala (4) also measured the response time of passing motorists. In one case he parked a car by the side of the road, and briefly opened the driver's door as a car approached. Measures were made of the time from the door opening until the approaching car began to move left. It was found that this displacement began an average of 1.5 seconds after the door opening.

In another study (5) subjects drove a test vehicle for "familiarization" purposes for some time, finally encountering an obstacle in their lane over a hillcrest. Response times to this stimulus ranged from 0.9 to 1.8 seconds.

The results of these investigations indicate that response times for drivers under normal states of alertness should be taken to be not less than 1.5 seconds. If allowance is made for less compelling stimuli, driver fatigue, drug and alcohol use, longer response times should be assumed.

THE HUMAN VISUAL SYSTEM UNDER NIGHTTIME DRIVING CONDITIONS

THE EYE - The eye has often been compared to a camera. Indeed, there are substantial similarities on a structural level. Figure 1 is a diagram of the eye, with some of the principal parts labeled. These can be described as follows:

The cornea is the transparent front surface of the eye through which light enters.

The lens is one of two media that bring light to a focus on the retina (the other is the cornea). The lens is flexible. It is suspended in a network of muscles that can change its focal length by causing it to become fatter or thinner. By so doing the lens can bring both near and distant objects to a sharp focus, a process known as accommodation.

The lens is an unusual structure in that it continues to add layers of cells throughout life. Since it cannot grow larger it becomes more dense and less flexible instead. The result of this is that the eye gradually loses its ability to focus up close. This is called presbyopia, and the result for many people is an eventual need for reading glasses or bifocals. The lens also becomes somewhat yellow with age, reducing the level of illumination reaching the retina, particularly from the blue end of the spectrum.

The iris is the colored portion of the eye. It functions to control the size of the opening in front of the lens (the pupil), regulating the amount of light that can enter. It is one of two mechanisms (the other other is the retina) that allow the eye to function through a very broad range of lighting conditions.

The maximum opening of the pupil becomes less with age, varying in diameter from about 7.5mm at age 20 to about 4.8mm at age 85 (6). In area, this is a change from about 44 to 18 square millimeters, meaning that nearly 2 1/2 times more light is getting by the iris in a 20 year old eye, compared to an 85 year old eye, under dark-adapted conditions.

The retina is the light-sensitive layer of the eye, the central portion of which is called the fovea. The retina covers about two-thirds of the interior of the eye and contains the light-sensitive cells. There are two types of cells, the rods and cones, which differ functionally as well as in their distribution throughout the retina.

The cones function at higher light levels (providing what is called photopic vision), and are wavelength sensitive, producing the sensation of color. Rods function at lower light levels (providing what is called scotopic vision), and are not wavelength sensitive. Hence, pure rod vision is in shades of gray. There is a middle range of light levels in which both rods and cones function. This is called mesopic vision. Typically, night driving is done under mesopic conditions (7).

Compared to rods, cones have far fewer neural interconnections, hence are capable of finer discriminations. Cones are found exclusively in the fovea, and in rapidly diminishing numbers as one moves away from the fovea. Rods are found throughout the retina, with the exception of the fovea.

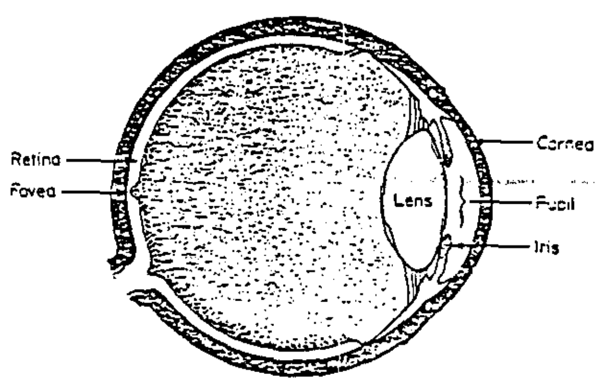


Figure 1. Diagram of the human eye.

VISUAL PERFORMANCE - Measurement of Visual Performance - The measure of visual performance with which most people are familiar is static acuity. Static acuity is a measure of the ability to distinguish fine detail in a stationary target. It is typically represented as a comparative figure, e.g., 20/20. The first number represents the performance of the person being assessed, and it does not change. The second number represents the performance of a "standard observer." A score of 20/20 means that the person being tested can resolve fine detail as well at 20 feet as can the standard observer. It does not mean "perfect vision," as people sometimes claim. A score of 20/40, which is sometimes set as the lower limit of acuity much better after the glaring vehicle has passed that the lesser effect of adaptation change goes unnoticed. Ottander (15) measured the readaptation time after moderate levels of headlamp glare and found it to be a maximum of two seconds. This represents a normal exposure. Adaptation time would be increased by more severe conditions, e.g., higher levels of glare, longer exposure.

VEHICLE LIGHTING SYSTEMS

INTRODUCTION - Humans are not creatures of the night by design. In order to be able to function adequately at night illumination is required. In the context of motor vehicle operation, this illumination may be provided by fixed lighting installations, by the vehicle's headlamps, or by a combination of the two.

There are street-lighting installations that are of such high quality that they make headlamps unnecessary, except possibly as vehicle markers. These are the exception, however. Many installations are of lesser quality, characterized by lower levels of illumination overall and considerable variation in pavement luminance from one area to another. Such systems can be deceptive, with the capacity to hide significant problems in the dark areas.

While there is no question that wide use of high-quality fixed illumination systems is desirable, they are costly to install and operate. As a result most people drive most of their nighttime miles on roads that are unlighted, or lighted at levels that make the illumination provided by the vehicle's headlamps necessary.

This section of the report will deal with motor vehicle headlamps. It will discuss the different types of equipment in use today, general problems in design, the performance that can be expected, and factors limiting performance.

LIGHTING EQUIPMENT - Virtually all vehicle headlamps offer two beams. The upper beam is designed for use when there are no other vehicles nearby in the forward field. Its design presents no serious problems. Of much greater concern is the low beam, which must provide adequate visibility while simultaneously protecting other drivers from excessive glare.

An inspection of Figure 2 will help in realizing how difficult this job is. The figure is a view of a straight, flat road. The numbers on the V axis show the distance, in feet, in front of the car. The dashed line in the upper left-hand quadrant shows the trajectory of the eyes of an oncoming driver. The numbers on that line also represent distance, in feet, from the car in the right lane.

The trick in low-beam design is to get as much illumination below the H-axis as possible to help the driver see, while controlling illumination above the H-axis to reasonable levels, because it causes glare for other

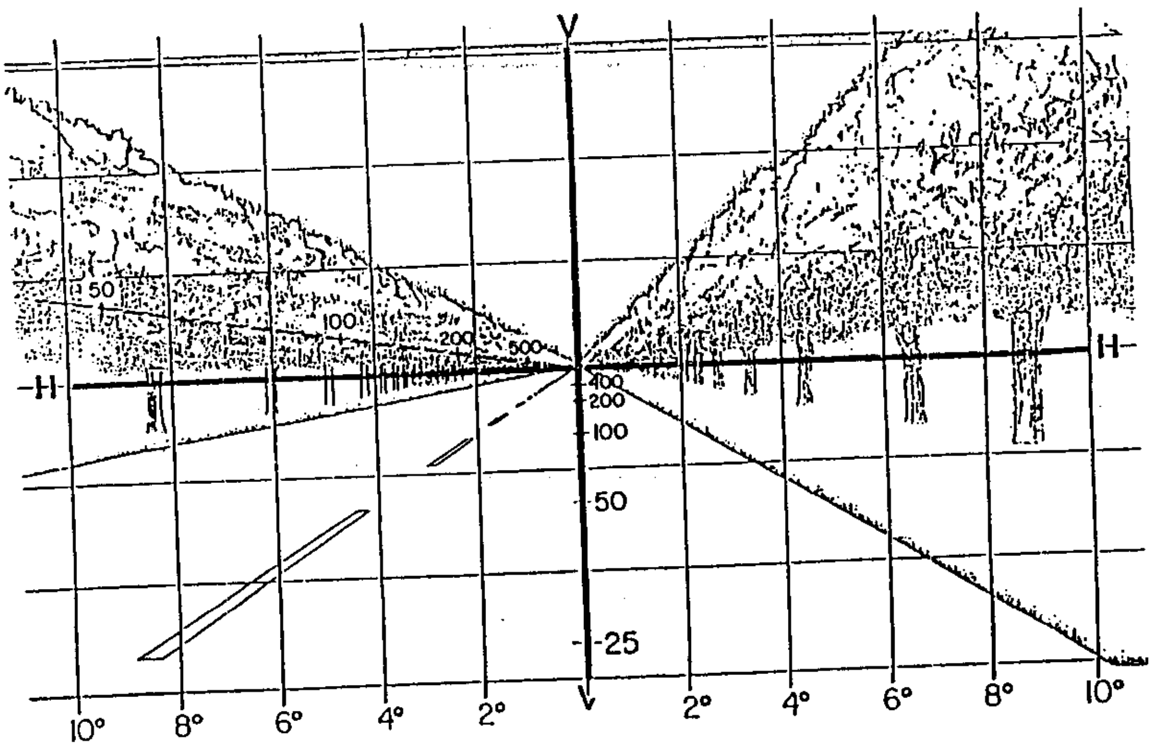


Figure 2. A headlamp's view of a road.

drivers. However, the angular separation between areas where illumination is helpful and where it is harmful is very small. Furthermore, roads tend not be be flat and straight like the one shown in Figure 2. Allowance must be made for the effects of road curvature, as well as for problems such as vehicle loading, and aim variance. Finally, some illumination must be projected above horizontal, to aid in seeing such things as signs.

Because of these and other considerations, what has emerged as the low beam pattern is the result of much compromise. A great deal of research (e.g., 16) suggests that it is probably close to optimum, at least for present-day technology.

There are two different low-beam patterns in use for automobiles in the world today. Lamps legal for use in the United States rely on lens prisms and some filament shielding to control illumination. They produce a pattern like the example shown in Figure 3. The introduction of halogen sources, stylized headlamps, and replaceable bulb units in recent years has had no significant effect on the beam pattern.

In lamps legal for use in much of Europe, and some other parts of the world, the primary control element is a small shield between the low-beam filament and the lower half of the reflector. This produces a beam pattern that looks very different from the US pattern. An example is shown in Figure 4. European headlamps are characterized by uniform illumination below horizontal, a sharp horizontal cut off, and generally lower levels of illumination above horizontal than US units. Despite the fact that the beam patterns from the two systems look very different, a great deal of research has shown that they perform about the same (17).

Motorcycle headlamps are covered by regulations that are different than those for automobiles and trucks. These regulations allow a much broader range of beam patterns, including the European system. As a result, motorcycle headlamps are available in a variety of patterns, sizes, wattages, and types of construction (18). The best of these units are about equal to automotive headlamps. Therefore, since most motorcycles have but one headlamp, they produce at best about half the illumination of an automobile. However, since motorcycle headlamps are generally mounted higher than those on cars, visibility distances provided the operators of the two types of vehicle are roughly equal (19).

FACTORS LIMITING LIGHTING SYSTEM PERFORMANCE - The Intensity-Visibility Distance Relationship - The illumination on an object varies inversely as the square of the distance from the source of illumination. For example, if an object has an illumination level X at distance Y from a light source, it will have an illumination level of 1/4 X at distance 2 Y. Based on this relationship, doubling the output of a headlamp, as recently became possible with high beams when the maximum output increased from 75,000 cd to 150,000 cd, should increase visibility distance by about 40%. Unfortunately, this is not the case. Figure 5, taken from Roper and Howard (20) suggests that an increase of about 20% is all that can be expected.

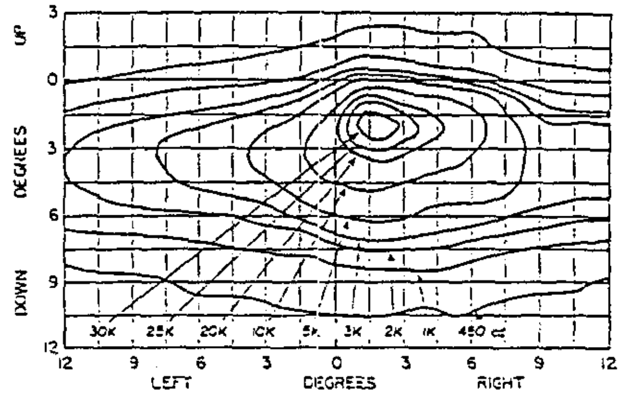


Figure 3. Isocandela diagram of U.S. low beam. Units are candelas (cd).

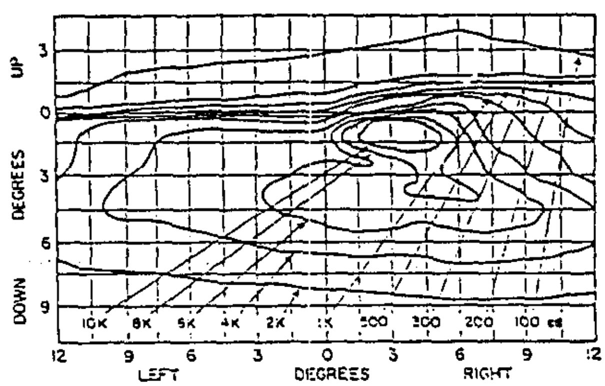
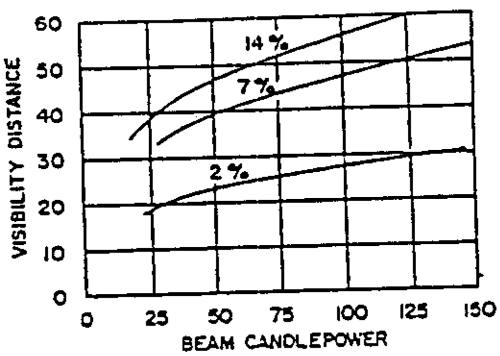


Figure 4. Isocandela diagram of E.C.E. low beam. Units are candelas (cd).

The reason that headlamp visibility distance does not increase as indicated by the distance squared law is partially due to factors such as atmospheric attenuation. But the main reason, as will be discussed later, is that contrast is far more important in determining whether something will be visible than is overall level of illumination. Increasing visibility distance is not a simple matter of increasing lamp output, even if the problems such an increase would cause could be ignored.

Glare - Glare is the result of brightness within the visual field that is sufficiently greater than the luminance to which the eyes are adapted to cause adverse effects on driver visibility and/or comfort. These effects are generally referred to as disability and discomfort glare respectively, although sometimes the latter is called psychological glare.



(From: Roper and Howard, 1938)

Figure 5. Visibility distance as a function of beam candlepower and target reflectivity (50). (Candlepower values are X 1,000.) (Visibility distances are X 10 feet.)

The term "disability glare" should not be construed to mean that the observer is completely blinded by the exposure, although that sometimes happens. Rather, it refers to a diminished visual capability. Disability glare arises from the fact that light entering the eye is scattered somewhat by the optic media, so that some of it ends up on other portions of the retina. This stray radiation reduces the contrast of objects imaged on the retina, and makes them more difficult to detect (21). The effect becomes more pronounced with age (22), compounding the problems older drivers face.

Sudden exposure to very bright light can cause obvious discomfort. Why this happens is not clear, but work by Fry and King (23) suggests that it may be due to minute fluctuations in pupil size. Discomfort glare may be no more than an annoyance, although there is the possibility of increased fatigue if the levels are high enough and persist long enough.

Since discomfort is a subjective phenomenon, there are difficulties in measuring it and establishing a reasonable upper limit. The most extensive and significant research on the subject in the context of automotive lighting has been reported by Schmidt-Clausen and Bindels (24). Some other work, conducted under field conditions (25), suggests that their recommendations may be somewhat conservative. It is an area where more work is needed.

Lamp Aim - To a very significant degree, headlamp performance depends on the units being properly aimed. Work reported by Hull, et al. (26) provides an indication of how much difference relatively small aim changes can make. For example, if headlamps are misaimed up by one degree, as might happen if a heavy load was placed in the trunk of a vehicle, visibility distance can increase by 60 to 75%. Unfortunately, glare for other drivers increases greatly as well. Misaim down by a degree poses no glare problems, but can reduce visibility distance by 24 to 45%.

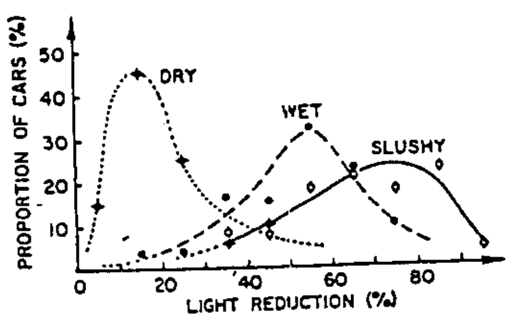
Maintaining proper aim is difficult, for two reasons. First, as noted earlier, the angular separation between areas of the forward field where illumination is desirable and harmful is small. As a result small amounts of misaim can be very significant. Second, there are many sources of aim error, some of which are difficult to control.

Misaim can arise from the lamp itself (e.g., improper filament position), by the lamp being incorrectly oriented in its mounting, and from the vehicle. Limited research also suggests that obtaining accurate aim through service outlets is a chancy business (27). Poor service can itself be a source of aim variance.

A recent survey on the condition of vehicle lighting equipment (28) found that headlamps were commonly aimed outside limits suggested by the SAE (plus or minus 4 inches at 25 feet). On cars four or more years old, only 25 to 30% of vehicles had both low-beam units aimed within SAE limits. Nearly 60% of vehicles less than one year old had both low-beam units within SAE specifications.

Recognizing that aim is a major limitation to the effectiveness of headlamps, considerable thought has gone into means for improving it (29). However, no radical changes are likely, and aim will likely continue as a significant problem in headlighting for the foreseeable future.

Effects of Dirt - Headlamps can become very dirty, particularly in wet weather. Dirt on the headlamps causes light to be absorbed and scattered, reducing useful illumination and oftentimes increasing glare to oncoming drivers. Figure 6, from Rumar (30) shows the results of measurements made on samples of vehicles under various driving conditions. Under wet and slushy conditions most cars had useful illumination reduced by more than half.



(From: Rumar, 1970)

Figure 6. Proportion of cars at gas stations having various degrees of light reduction in the central part of the high beam caused by dirt under three road conditions.

In an effort to reduce the detrimental effects of dirt on headlamps, cleaning systems have been developed. The most common are wiper-washer systems like those used on windshields. High-pressure spray devices have also been developed. Such systems are common in some parts of the world, but have not yet come into use in this country.

VISIBILITY AT NIGHT WHEN DRIVING

INTRODUCTION - A pedestrian wearing dark clothing walks along the right edge of an unlighted road, with his back to traffic. A car, using low-beam headlamps, and travelling about 35 mph, strikes the pedestrian, inflicting serious injuries. At trial the driver of the car claims that he saw the pedestrian just before impact and did not have enough time to stop or swerve out of the way. However, the plaintiff produces an expert who, quoting from a manual for drivers, says that visibility distance with low beams is 350 feet. On that basis the driver should have had plenty of time to detect the pedestrian and avoid the impact. Who is the jury to believe, the driver, who has an obvious reason for wanting the visibility distance to be as short as possible, or the (presumably unbiased) expert? This section is intended to provide an answer to this question, together with the reasons for it.

THE IMPORTANCE OF CONTRAST - Contrast refers to characteristics that cause something to appear different or separate from something else. The eye responds to contrast. Under daylight levels of illumination there are a variety of forms of contrast available (e.g., color, texture, brightness). In addition, the visual system is operating at the highest level of sensitivity and has the greatest capability of distinguishing differences. However, under night driving conditions brightness contrast is generally the only form of contrast of any consequence, and the visual system has a reduced capability for distinguishing differences. Thus, in order to be seen at night, objects must be sufficiently brighter or darker than their backgrounds. Sometimes objects can be seen at great distances silhouetted against a bright background (e.g., the headlights of an oncoming car, a road surface illuminated by streetlights, the lights of a shopping center). More typically the object must be illuminated by the headlights of the approaching car until it is enough brighter than the background to be seen.

Assuming the target object is seen against something other than the sky, the job of the headlamps in providing the necessary brightness contrast is complicated by the fact that they illuminate both the target and its background. Table 2 (from Bhise et al. [16]) shows the reflectivity levels associated with common highway backgrounds. Clearly, someone wearing dark clothing may be seen against a background having similar reflective characteristics and under conditions where contrast would increase very slowly as the car approached.

VISIBILITY DISTANCE - To return to the hypothetical mishap described at the start of this section, at what distance should a reasonably alert and prudent driver have been able to detect the pedestrian? To provide an answer, we will rely on data developed in a field test of different headlighting systems (25).

In the study in question subjects drove or rode in a car that was operated on a private road. There were four possible targets. Three

Table 2

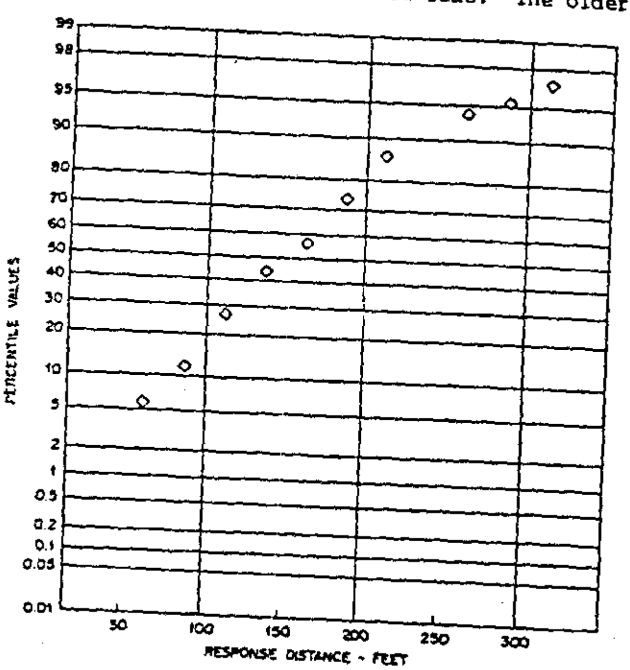
Reflectivity Levels of Common Objects

Target	Reflectance	
Pine Trees	.02-.08	
Grass	.08-.16	Long, dormant, pale green
Grass	.10-.18	Lush green, closely mowed
Forest	.02-.26	Mixed green
Dirt	.23-.43	Packed, yellowish
Asphalt	.06-.13	Oily with dust film
Concrete	.25-.37	White aged
Pedestrians	.055	Median of 54 winter coats
Pedestrians	.03	5th percentile winter coats

(From: Bhise et al., 1977)

of these were clad in blue denim, were of about equal width, and differed in height. One was an experimental assistant (pedestrian). The other two were, respectively, 2.5 feet (76mm) and 6 inches (15mm) high. The fourth target was the pedestrian, wearing a white vest. One or more of these targets could appear on each run though the course, at any point in the course, and on either the right or left of the test vehicle. The subjects had to detect the target, identify it by size, and press an appropriate button on a box in their lap. The distance from the target at which they pressed the correct button was recorded.

Figure 7 gives the results of this study for the pedestrian target, standing one to two meters to the right of the vehicle, using US low beams, and with no glare. It is based on about 60 trials from 23 young subjects. Under these conditions, the 5th and 95th percentile response distances were about 50 and 250 feet (15 and 76m), respectively. (This means that on 5% of the trials the subjects responded at 50 feet or less, and on 95% of the trials they responded at 250 feet or less.) If the same target was located to the left of the test vehicle, the 5th to 95th percentile range was from about 25 to 125 feet (8 to 38m). The 5th to 95th percentile response distances to the pedestrian wearing the white vest were about 150 to 450 feet (46 to 137m) on the right side and about 100 to 350 feet (30 to 107m) on the left side. The older subjects did less well, their response distances averaging about 60% of those recorded for the younger subjects.



(From: Olson and Sivak, 1983)

Figure 7. Normal probability plot of response distances measured to a dark-clad pedestrian standing on the right edge of the road using standard, low-beam headlamps. No glare, young subjects.

To illustrate what these data mean in practical terms, estimates were made of the percent of trials in which the subjects would not have been able to stop short of the pedestrian from speeds of 35, 55, and 70 mph (56, 88 and 113 km/h). The original data were taken at 25 mph (40 km/h). It was assumed that the subject hit the brake, instead of pressing a button, and brought the car to a stop at a deceleration of 0.75 g. It was further assumed that the brake application was made at the same distance from the target as the button press regardless of speed.

Under these assumptions, with the pedestrian on the right, the percent of trials in which young subjects would <u>not</u> have been able to stop short of the pedestrian were as follows:

35 mph (56 km/h)	1
55 mph (88 km/h)	45
70 mph (113 km/h)	89

Because most of the energy from a low beam is directed to the right side of the road, positioning the pedestrian on the left made the results somewhat worse:

35 mph (56 km/h)	22
55 mph (88 km/h)	95
70 mph (113 km/h)	>99

As already noted, the older subjects did not do as well. There were fewer of them in the study, so the following analyses are based on averages across several lighting systems that were tested. Since some of these systems were more powerful than the US low beams, the results may be somewhat conservative. The first analysis is for the pedestrian on the right:

35 mph (56 km/h)	22
55 mph (88 km/h)	83
70 mph (113 km/h)	98

And, with the pedestrian on the left:

35 mph (56 km/h)	49
55 mph (88 km/h)	94
70 mph (113 km/h)	98

An analysis was also made of the condition in which the pedestrian was wearing the white vest. For the young subjects, with the pedestrian on the right, the results were as follows:

35 mph (56 km/h)	<1
55 mph (88 km/h)	3
70 mph (113 km/h)	24

With the pedestrian on the left:

35 mph (56 km/h)	<1
55 mph (88 km/h)	9
70 mph (113 km/h)	48

The analyses just presented suggest that when confronted with a low-contrast object, such as a pedestrian wearing dark clothing, low-beam headlamps may not provide adequate detection-identification distance at speeds in excess of about 35 mph. If the pedestrian is approaching from the left side of the vehicle, or if the driver is elderly, the situation can be appreciably worse. However, pedestrians who must venture forth at night can make themselves much more likely to be seen by wearing light-colored garments.

While these data indicate a potentially serious problem in night visibility while operating a motor vehicle at medium and higher speeds, it should be recalled that they are based on a structured test in which the subjects were alert, free from drugs and alcohol, aware of the purpose of the test and the nature of the targets, and had no concerns with other traffic. Because of these conditions, the response distances described earlier are probably greater than could reasonably be expected in the real world.

An interesting study reported by Roper and Howard (20) provides some indication of the difference in visibility distance between structured studies and the real world. The subjects in Roper and Howard's study were taken out to conduct "subjective evaluations of headlamps." After a time they were told the test was complete and they should drive back to the starting point. Without the knowledge of the subject, a dark-clad mannequin had been set up in the return lane. Measures were made of the distance from the mannequin at which the subject released the accelerator. With this "surprise" phase completed, the subjects were briefed on the true purpose of the study and then asked to back up and approach the target again, releasing the accelerator as soon as they could see it. Under the second, "alerted," condition response distances averaged twice those obtained in the surprise trial.

Roper and Howard's results may seem extreme. However, they appear reasonable when some of the differences between the surprise and alerted conditions are considered:

1. In the alerted condition the subjects knew where the target would appear and could fixate that spot foveally. It is likely that detection in the surprise condition was accomplished peripherally.

2. Knowing the nature of the target makes it possible to "detect" it using subtle cues that may not be adequate in the absence of such special knowledge.

3. With full knowledge of the nature of the test, the subjects' expectancies are much different than they would be in normal driving. Under test conditions they typically focus their attention on the target detection task and are less likely to be distracted by other things that might be going on.

In accident reconstruction, an investigator is sometimes interested in estimating the distance at which a driver should have been able to detect the target of interest. Such tests are often set up much like the alerted portion of the Roper and Howard study. It is possible to obtain useful information by such an exercise. However, for the reasons given above, it is essential that the investigator understand that the likelihood of something being detected at all, as well as the distance at which it should have been detected, will probably be substantially overestimated.

To return to the question posed to the jury by the hypothetical case described at the start of this section, the data presented here suggest that the version told by the defendant driver is more believable than that told by the "expert." The fact is that individuals who walk in traffic at night, relying on the drivers of oncoming cars to see them, are placing themselves in grave danger. Unfortunately, this situation is unlikely to be resolved by improvements in vehicle lighting anytime in the near future. Because of this, it is important that efforts be made to: (1) improve the understanding of roadway users concerning limitations in nighttime visibility, and (2) increase the contrast characteristics of objects in the road, particularly people, by encouraging the wearing of light-colored garments at night and by wider use of retroreflective materials.

NIGHTTIME DRIVING HABITS - Having discussed at some length the visibility problems associated with night driving, it is reasonable to point out that people do not drive much slower at night, and ask why.

There is evidence that people overestimate the visibility provided by vehicle lighting systems. For example, Allen et al. (31) had subjects stand along the side of a road and estimate the distance at which an approaching driver could see them. At the same time the driver indicated the distance at which he/she could see each pedestrian. On average, the pedestrians' estimates were about twice the distance at which they actually could be seen. This work was extended and confirmed by Shinar (32). There are no comparable data for drivers, but the behavior of many of them while operating a vehicle at night suggests that they think they can see a good deal better than they really can. If this is true, we have an unfortunate combination of errors, with both drivers and pedestrians thinking visibility is better than it is.

Leibowitz et al. (33) have advanced a theory that may account for the fact that people often drive well in excess of speeds that would allow them to stop if confronted with an unexpected, low-contrast object. The theory assumes two independent modes of processing visual information. One of these is called the "focal" mode. It is concerned with object discrimination and identification. Focal functions are optimal in the foveal area, and are affected by level of illumination and refractive error. The other mode is called "ambient." It is concerned with spatial orientation. Spatial orientation can be accomplished in the foveal area, but, unlike the focal functions, it is adequate in the peripheral areas as well. In addition, ambient functions are much less sensitive to illumination levels and refractive error than focal functions. Under night driving conditions there is a selective degradation of these two modes, with focal vision being much more affected. This means that we suffer relatively little loss of ambient vision, which is useful for maintaining lateral position on the road. The fact that focal vision is greatly reduced is less appreciated because the demands on it are intermittent. Thus, since the driver can carry out the routine control function about as well at night as during the day, overconfidence concerning the whole driving task may be generated.

FACTORS THAT DEGRADE VISUAL PERFORMANCE

INTRODUCTION - The information on driver visibility offered in the preceding section is based on tests run under ideal circumstances. Conditions in the real world are not always ideal. In fact, there are a great number of conditions that can affect a driver's visibility. Some of these have already been mentioned, i.e., glare, aim and dirty lamps. In this section a number of other conditions will be discussed. These fall under three general headings, based on whether they arise from the environment, the vehicle, or the driver.

PROBLEMS ARISING FROM THE ENVIRONMENT - In general, "environmental" problems refer to anything in the atmosphere that interferes with vision. Most often these would be in the form of precipitation or fog. However, they also include conditions such as smoke, haze and dust. At night all of these conditions have in common the characteristic that they absorb and scatter light to some degree. This absorption and scattering has two effects. First, less light from the vehicle's headlamps reaches a target object, and less of the light reflected by the object is returned to the driver's eyes. Second, some of the scattered illumination is reflected back into the driver's eyes, causing the atmosphere to appear to light up. This reduces the target object's contrast, making it more difficult to detect.

"Wet" conditions such as rain, and sometimes snow and fog, create other problems as well. The most immediately noticeable is the fact that the windshield becomes wet, and requires wiping in order to maintain reasonable visibility. Even under the best of conditions visibility is reduced when the windshield is wet. If the wipers are worn, if the windshield is badly pitted or scratched, if the car is moving at high speed, or if the rainfall is very heavy visibility may be reduced a great deal (34, 35, 36, 37).

A film of water on the road can greatly increase the driver's problems in determining his/her lateral position as well as where the road is going. There are two problems. Normally the road surface, being rough, acts as a diffuse reflector. It reflects some of the illumination from the vehicle's headlamps back into the eyes of the driver, causing the pavement to appear relatively bright. The first problem is that water fills in the small voids in the pavement surface, and creates a smooth film that acts as a mirror. As a result headlamp illumination is reflected forward, causing the road to appear very dark and increasing glare for oncoming motorists. Under such conditions delineation becomes very important.

All of which brings us to the second problem. Many forms of delineation also suffer when wet. The most common form of delineation, painted lane lines, are reflectorized by sprinkling them with glass beads before the paint dries. Water forms a film over these beads, changing their refractive index so they no longer function as retroreflectors. As a result, painted lane lines seem to disappear when the pavement is wet.

However, not everything is lost when the pavement is wet. The headlamp illumination reflected off wet pavements can significantly increase the brightness of objects such as signs in the forward field, compensating to some degree for the loss in visibility due to other causes (38).

The effect of water on pavement visibility has been a matter of concern for some time. Raised pavement markers have been the best solution so far, and are used extensively in the south and far west. However, they present difficulties in snow-belt states because plows tend to destroy them. A great deal of research has been carried out (e.g., 39) to find a satisfactory and economical solution to this problem. Work is still continuing.

PROBLEMS ARISING FROM THE VEHICLE - One of the most critical components in the vehicle from a standpoint of driver visibility is the windshield. Windshields must meet a number of criteria, some of which are specialized (e.g., protection in crash situations). But, what a windshield does most is allow the driver to view the road. Hence, good optical quality is very important.

Unfortunately, windshields lead a hard life. Subject to continuous bombardment by airborne particles, occasional encounters with larger objects, abrasive action from the wipers and careless efforts at cleaning, plus films that build up on both sides of the glass, many windshields have optical characteristics that significantly degrade driver vision, particularly at night. Contaminants, surface pitting and scratches scatter light passing through the glass, reducing visibility in general and increasing the effects of glare. Rompe and Engel (40) showed that the probability of detecting targets of varying contrast decreased from 91% with a clear windshield to 73% with a windshield having a haze level of 4.9%. Performance was greatly degraded when glare sources were introduced.

Heat-absorbing (tinted) windshields have been an object of some controversy for a number of years. The purpose of the tinting is to reduce the sun load on the vehicle's occupants and interior, thus improving comfort on hot days. While it does this effectively, the tinting also reduces visible light transmitted though the glass. Because of this, some persons (e.g., 41) have argued that tinting the entire windshield is a bad idea, due to loss of visibility at night.

The loss in transmitted light due to windshield tinting is significant. A clear windshield, installed at an angle of 60 degrees from vertical, will transmit about 80% of light passing through parallel to the ground. A tinted windshield will transmit about 68% under identical conditions. This translates to an effective loss of illumination on objects in the forward field, and a consequent loss in visibility. Given the already inadequate visibility provided drivers, as discussed in Section 4, further reductions may seem difficult to justify.

The argument concerning heat-absorbing windshields comes down to balancing advantages and disadvantages. There have been a number of studies of visibility distance at night comparing clear and tinted glass (42, 43, 44). Generally, these have shown losses in visibility distance associated with tinted glass ranging up to about 6%, depending on the target and test conditions. Whether this loss in visibility under night driving conditions is worth the gain in comfort under warm, sunlit conditions is something that will apparently continue to be debated.

PROBLEMS ARISING FROM THE OPERATOR - Problems with the operator that may affect visibility can be temporary or permanent. Temporary problems include fatigue, psychological states such as stress that may reduce attention to the driving task, and the effects of drugs and alcohol. Alcohol has been shown to be a contributing factor in about half of fatal and serious-injury accidents. Other temporary degraded states are probably also very significant. However, this section will deal with certain problems that are permanent in nature. The reason is that many of the temporary degraded states have received much attention in recent years. The areas that will be discussed here are also important, but have received far less attention.

Aging - One of the most easily observed effects of aging on vision comes about when one can no longer read comfortably and reading glasses or bifocals must be used. This condition is due to the increasing inflexibility of the lens, and is called presbyopia. Although it may make it more difficult to read information presented on the dash panel, presbyopia is not typically a problem in motor vehicle operation.

However, other effects of aging on vision may be a significant problem. For example, visual acuity, since it involves the ability to resolve fine detail, affects the ability to read signs along the road, as well as the ease with which various conditions can be detected and identified. Studies have shown a relationship between acuity and age. On average, acuity peaks at about age 15, and declines steadily thereafter, reaching about one-third peak value at age 80 (45).

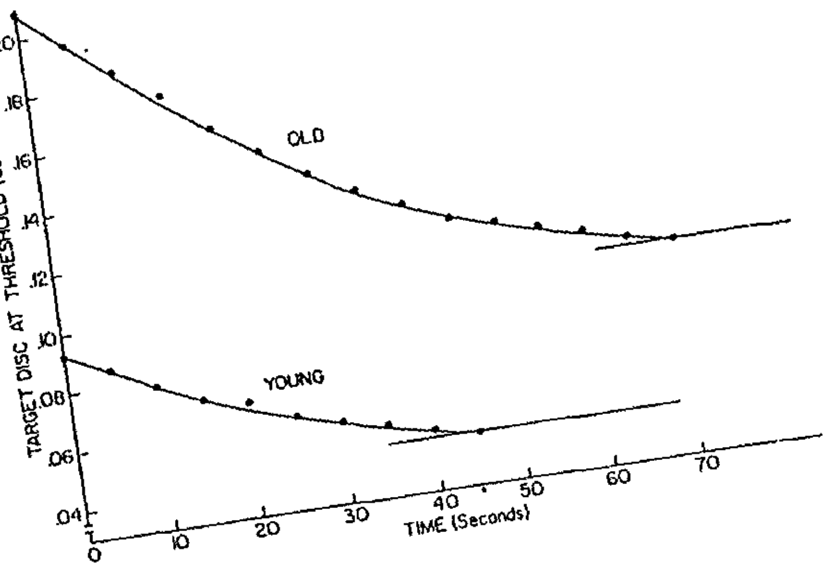
The most critical condition is at night. In general, acuity and other visual functions decline as the level of illumination decreases. However, the effects are more marked in the elderly. It is not completely clear why these losses in visual capability come about. It has been known for some time that the minimum level of illumination to which the eye can adapt, as well as the time to adapt from one level to another, increases with age (46). Three possibilities (22) are: (1) a reduction in the oxygen supply to the retina; (2) a reduction of the maximum opening of the iris; and (3) yellowing of the lens. All of these factors may play a part. Whatever the reason, as illustrated by the safe stopping calculations presented in the preceding section, older persons tend to do less well than younger persons on visual tasks at low levels of illumination. Indeed, even when matched in daytime acuity, Sivak et al. (47) found that older subjects were able to read highway signs at only about two-thirds the distance of the young subjects at night.

The disabling effects of glare are also more pronounced in older persons. Not only are older subjects more affected by glare, it takes them longer to recover when the glare source is removed. Figure 8 (48) shows the results of measures made on threshold detection of a disc target starting when a glare source is extinguished. The older subjects were much more affected by the glare when it was on, and it took them about 50% longer to adapt to the ambient level. Note too that the target disc had to be about twice as bright to be visible to the older subjects at the ambient level.

Night Myopia - Myopia is commonly referred to as near-sightedness. It results when the lens-to-retina distance in the eye is too great. With this condition close objects can be brought into sharp focus on the retina, while more distant objects are brought into focus in front of the retina, resulting in a blurred image.

In total darkness the eye accommodates to an intermediate state (dark focus) that varies from person to person. Owens and Leibowitz (49) have shown that the eye tends to accommodate to distances between infinity and that represented by dark focus as illumination levels are reduced. The result is "night myopia." Because most events of consequence to a vehicle operator occur at visual infinity (i.e., beyond about 20 feet), an eye that is accommodated to an intermediate distance will see them less well.

Available data indicate that a great number of people may have night myopia to some degree. However, there are large individual differences. In extreme cases, individuals may have a focus



(From: Olson and Sivak, 1981)

Figure 8. Luminance required on target disc to provide threshold visibility as a function of time after onset of glare.

point only a few feet in front of them, with objects in the far field seriously blurred. Fortunately, most people are much less affected.

An obvious solution to the problem of night myopia is to measure individual accommodative changes and prescribe corrective lenses to be worn while driving at night for the more serious cases. There are two problems in doing this. First, a person may have serious night myopia and not be aware of the fact. Thus, affected individuals are not likely to seek assistance voluntarily. Second, it is difficult to carry out conventional refractive measures at low levels of illumination, and night myopia cannot be predicted from measures taken at high levels of illumination. So, even if an individual felt the need, an Ophthalmologist or Optometrist could not conduct the necessary tests and write a prescription. The development of a laser optometer (50) has made such measures practical. There may be merit in screening for night myopia, with corrective lenses required for night driving where appropriate, just as we require corrective lenses for daytime operation.

Expectancy - A safety agency once offered a new slogan that was given wide publicity. On billboards and in other media they touted the theme "good drivers expect the unexpected." It's a catchy phrase, and the idea probably sounds reasonable to many people. Certainly, no one will argue the point that drivers should be alert and attentive to the driving task. However, taking the slogan in a literal sense, the variety of things that could happen is so vast that it is unreasonable to expect drivers to be prepared for all of them all of the time. In fact, the soundest approach to safe traffic management is to minimize the unexpected. One of the major efforts of traffic engineering in the last several decades has been in just this direction. Through publications such as the Manual of Uniform Traffic Control Devices (MUTCD), and concepts such as Positive Route Guidance (1), considerable progress has been made in producing a nationwide traffic control system that provides necessary information in a timely manner and minimizes nasty surprises.

Based on their driving experience, people develop expectations about matters such as traffic control devices, roadway design, and driver behavior. This is true both night and day, however it becomes more important at night because so much of the information available during the day is lost when it becomes dark.

Two general types of expectations have been identified, a priori and ad hoc (51). A priori expectancies come from general experience. Examples are the assumption that freeway exits will be on the right, that curves can be taken at the speed limit or will be otherwise posted, and that no-passing zones will be marked with a solid yellow line and signs. A priori expectancies are the basis for assumptions about traffic operations that people bring with them whenever they take to the road. Ad hoc expectations are based on very recent experience. For example, a driver encountering a road with numerous sharp curves that require a speed reduction will adapt his/her expectations to that situation.

The important points to be made here are that all drivers have expectations, that these expectations are based on exposure to (generally) sound traffic engineering practice, and that conforming to driver expectations facilitates traffic flow and minimizes accidents. When these expectations must be violated (construction work that requires lane closures and left-hand exits from freeways are good examples) great care must be taken to alert approaching drivers to the condition in time so that they can make the necessary adjustments. What traffic agencies, police and accident investigators should not do is adopt an attitude excusing the existence of conditions that violate driver expectations, as reflected in statements that start out "If only he/she would have been paying attention. . ."

Judgments of Closing Speed - Missing his exit from a freeway, a truck driver slows and looks behind him. It's two AM and there is no traffic in sight. The driver decides to stop and back up the quarter mile to the exit rather than go several miles out of his way by proceeding to the next exit and turning around. Staying in the right-hand lane, he backs up for ten seconds or so, then sees a car approaching in the distance. The driver stops and waits for the car to pass. He does not activate the emergency flashers. The car continues to approach in the right lane, and swerves left too late, striking the left-rear corner of the truck. At trial the defendant produces an "expert" who claims that there was no excuse for the driver of the approaching vehicle not seeing the truck, because it was well and properly lighted. The expert is perfectly correct in maintaining that the driver should have seen the truck. He is wrong in inferring that nothing more than detection was required.

Successful driving requires frequent interaction with other vehicles. It seems clear that vehicle operators have to be able to judge speed and spacing relationships to a reasonable degree in order for the system to function adequately. However, research indicates that there are two issues involved. Drivers are reasonably accurate in determining whether the spacing between their own and a lead car is opening or closing (52), but appear to be poor in estimating the rate of change (53). Due to the reduced number of cues available, this situation is probably worse at night.

In a situation such as that described, what these data suggest is that an overtaking driver could discern from a considerable distance that he/she was closing on the truck ahead, but could not determine that there was a large speed discrepancy until much closer. Here expectancy may come into play. Since stationary vehicles are extremely rare events in freeway traffic lanes, the approaching driver is likely to initially assume that the truck is moving, and the speed discrepancy is relatively small. By the time the gap has closed to the point where the speed discrepancy is obvious, it may be too late to avoid a collision.

Because of this limitation in human visual perception, the causative factor in accidents like the one described at the start of this section is often failure to identify the dynamic state existing between the vehicles, not failure to detect the lead vehicle. For this reason it is important that vehicles that are stopped or moving much slower than other traffic be distinctively marked. Emergency flashers are effective for this purpose because flashing lights have great attention-getting power, and the system has come to be identified with stopped or slow-moving vehicles.

CONCLUSIONS

This paper has been concerned with problems in driver visual perception under nighttime conditions. Three general points will be noted as a summary.

First, the visual system is constructed in a way that allows information to enter from a very wide field forward of the observer. However, the structure of the system is such that only the small portion of the field that falls on the fovea of the eye can be observed with maximum clarity. Because most of the visual field is peripheral, most unexpected objects or conditions must be detected while in the periphery. Since information is processed serially (i.e., one item at a time), and the information being processed at a given time is probably located on the fovea, the peripheral information not only must be more conspicuous than if it were seen foveally, but it must compete with other information for the driver's attention. If these considerations are ignored, reconstructions of a situation that are used to estimate "visibility distance" or some such parameter can yield very misleading results.

Second, especially on low beam, vehicle lighting systems do not provide enough illumination to ensure that low-contrast objects will be detected in time at anything other than very low speeds. It is target contrast, not amount of illumination, that has the major effect on target visibility. Pedestrians can greatly increase the probability of their being seen by drivers by wearing light colored clothing at night, or, better yet, retroreflective materials. Due to limitations on beam design, the visibility distance provided by automotive lighting systems will probably not improve significantly in the foreseeable future.

Third, there are a number of variables that can affect driver visibility under nighttime operating conditions. These may arise from the environment, the vehicle or the driver. The accident investigator must be aware of the effects of variables such as these and, when relevant, include them in his/her evaluation, to the extent that they can be assessed.

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We Would Like To Thank Each And Every One Of You Who Participated In Our Survey! We At Snow Glow® Inc Are Concerned About The Safety Of Snowmobilers And We Were Very Pleased To Know That We Are Not The Only Ones!

Congratulations to Kevin from Alaska, Gerry from Canada and Michael from Sweden! They are the 3 Winners for a Free Hazard Lighting System!

Again... Thank You, the Snowmobiler's, for Letting Us Know How You Feel About Safety!

	Under 21	21 - 35	36 - 45	46 - 55	Over 55
Age & Sex	25	47	43	13	7
Years Riding 1-5	9	5	6	.	.
Years Riding 6-10	10	5	4	1	1
Years Riding 11-15	2	21	13	.	.
Years Riding 16-20	.	9	11	5	3
Years Riding Over 21	.	4	8	7	3
Night Riding Do Not Ride	.	.	1	.	.
Night Riding Less than 10%	9	4	1	1	2
Night Riding 10-50%	12	22	24	10	5
Night Riding Over 50%	4	21	17	2	.
Safety Course? Yes	16	27	19	4	3
Safety Course? No	9	19	22	8	4
Concerned if broke down about possible collision? Yes	21	40	40	12	1
Concerned if broke down about possible collision? No	9	19	22	8	4
Purposely stop at night at all? Yes	16	35	36	8	2
Purposely stopped at night at all?No	8	5	5	1	5
Carry Supplemental Lighting? Yes	16	35	36	8	2
Flashlight?	16	30	36	9	6
Strobe?	.	.	4	.	.

Other?	1	10	6	.	1
Carry Supplemental Lighting? No	.	7	8	.	.
If you stop, do you leave sled on?	2	10	14	3	1
Do you run back to sled to start?	4	11	12	1	.
Do you park off trail and hope not to get hit?	6	5	11	1	.
Have you ever been lost or broken down? Yes	5	14	20	4	.
Have you ever been lost or broken down? No	7	28	12	6	6
Can you see benefit of Hazard Lights on Snowmobiles? Yes	25	45	41	13	6
Scale Rate of Hazard 1	.	.	1	.	.
Scale Rate of Hazard 2	.	.	.	.	.
Scale Rate of Hazard 3	.	1	.	.	.
Scale Rate of Hazard 4	.	1	1	.	.
Scale Rate of Hazard 5	5	3	1	.	4
Scale Rate of Hazard 6	1	2	1	.	.
Scale Rate of Hazard 7	1	3	3	.	.
Scale Rate of Hazard 8	8	24	5	1	1
Scale Rate of Hazard 9	.	1	7	4	.
Scale Rate of Hazard 10	16	6	20	8	.

Updated January 25, 2002

We Appreciate Your Interest In The Sport of Snowmobiling.

Respect Yourself and Others...Be Safe, Be Smart & Be Seen!

Please come visit us again soon!

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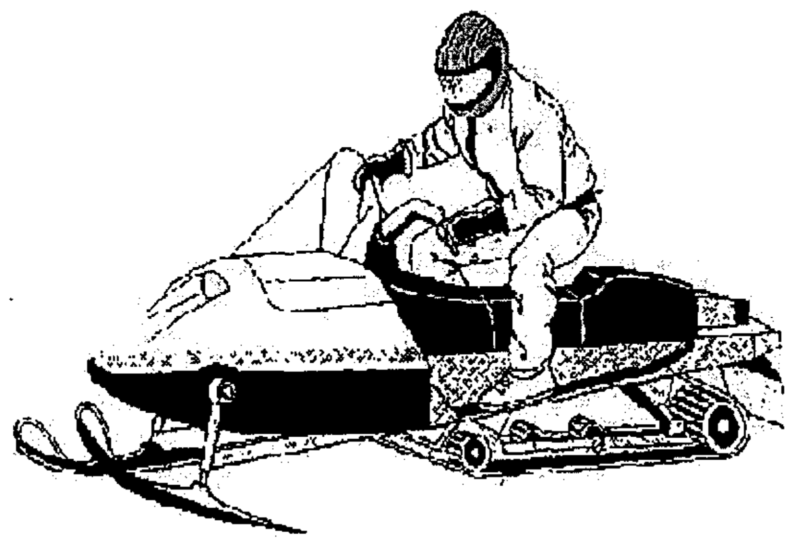
Consumer Product Safety Commission

Safety Commission Warns About Snowmobile Hazards

CPSC Document #541

The U.S. Consumer Product Safety Commission estimates that each year about 110 people die while riding snowmobiles. The Commission estimates that about 13,400 hospital emergency room-treated injuries occur each year with snowmobiles. Approximately two-fifths or 40 percent of the reported deaths resulted from colliding with trees, wires, bridges, and other vehicles. Some deaths occurred when the snowmobile rolled to the side in a ditch or stream and pinned the operator under the vehicle. Deaths also have occurred when the snowmobile entered water, mostly when it was operating on ice and fell through.



CPSC recommends the following safe snowmobiling rules for recreational snowmobiling:

1. Never drive your snowmobile alone or on unfamiliar ground Have someone ride along with you, so you can help each other in case of breakdown or accident.

2. Drive only on established and marked trails or in specified use areas.

3. Avoid waterways Frozen lakes and rivers can be fatal. It is almost impossible to judge adequate ice coverage or depth.

4. Avoid driving in bad weather. Check warnings for snow, ice, and wind chill conditions before starting

. 5. Watch the path ahead to avoid rocks, trees,

7. Don't hurdle snowbanks You have control only when your skis are on the ground.

8. Learn the snowmobile traffic laws and regulations for the area. Many states prohibit using snowmobiles on public roads Some states have mini-mum age requirements for drivers.

9. Be sensible about stopping at roads or railroad tracks. Signal your turns to other drivers Avoid tailgating Control speed according to conditions.

10. Use extra caution if driving at night, because un-seen obstacles could be fatal Do not drive faster than your headlights will allow you to see Do not open new trails after dark.

fences (particularly barbed wire), ditches, and other obstacles.

6. Slow down at the top of a hill A cliff, snowbank, or other unforseen hazard could be on the other side.

11. Never drink while driving your snowmobile. Drinking and driving can prove fatal.

12. Be sure the snowmobile is properly maintained in good operating condition. Some cases report that the throttle sticks, leading to loss of control Snowmobiles manufactured before 1983 may not have a "throttle interruption device" designed to shut off the snowmobile in the event the throttle sticks.

009403

The U.S. Consumer Product Safety Commission protects the public from the unreasonable risk of injury or death from 15,000 types of consumer products under the agency's jurisdiction. To report a dangerous product or a product-related injury, you can go to CPSC's forms page and use the first on-line form on that page. Or, you can call CPSC's hotline at (800) 638-2772 or CPSC's teletypewriter at (800) 638-8270, or send the information to info@cpsc.gov. Consumers can obtain this publication and additional publication information from the Publications section of CPSC's web site or by sending your publication request to publications@cpsc.gov. If you would like to receive CPSC's recall notices, subscribing to the email list will send all press releases to you the day they are issued.

S

SNOWMOBILING

American Council of Snowmobile Associations

State Laws and Rules

All states have laws and rules regarding the operation of snowmobiles. The following is a state-by-state summary of these rules.

Alaska

Trail Permits are not required for out of state snowmobilers. Snowmobiles do not require insurance. Helmets not mandatory. Limited roads open. You may not ride road shoulders and ditches. No specified speed limits. Point of Sale Registration Required - $10.00 for 2 years. Decals & Registration # Required.

Arizona

There are 500 miles of groomed trails in Arizona. Registration Fee: $0

California - Nevada

There are 1,800 Miles of groomed trails in California and Nevada. Trail permits are not required for out of state snowmobilers. All Roads are open for snowmobilers to use. Road shoulders & road ditches are not open for snowmobilers. Helmets are not required. There are no posted speed limits. 15 mph speed limit in congested areas around lodges. Snowmobiles must be licensed or purchase a non-resident permit if your state does not require licensing (i.e. Nevada). Registration Fee: $21 for two years.

Colorado

There are 2,000 miles of groomed trails in Colorado. Trail permits are not required for out of state snowmobilers. All roads are open to snowmobilers. Snowmobilers may ride the road shoulders and ditches. Helmets are not required. Speed limits are as posted. Registration Fee: $15.25 a year.

Idaho

There are 7,200 miles of groomed trails in Idaho. Trail permits are required for out of state snowmobilers. For more information on trail permits, contact: Parks & Recreation, Attention Snowmobile Registration, P.O. Box 83720, Boise, ID 83720-0065. All roads are not open to snowmobilers. Snowmobilers are not allowed to ride the road shoulders and ditches. Helmets are not required. Speed limits are 45 mph on groomed trails only. Registration Fee: $21 a year.

Illinois

There are 2,150 miles of groomed trails in Illinois. Trail Permits are not required for out of state snowmobilers. All roads are not open for snowmobilers. Snowmobilers are allowed to ride the road shoulders if 10feet from paved roadway. May legally ride in the road ditches. Helmets are not required. No posted speed limits. Snowmobiles must have adequate mufflers and operating brake lights. DUI Law is the same as for automobiles - .08. Registration Fee: $12 for three years.

Indiana

Trail permits are not required for out of state snowmobilers. Most snowmobile clubs have in their by-laws that snowmobilers must carry insurance. Helmets are not required. Roads open to snowmobilers varies from County to County. Road shoulders are open to ride in most Counties. No posted speed limits. A snowmobile registered to a non-resident of Indiana may operate under the authority of the registration for a period not to exceed twenty (20) days in one (1) year. Registration Fee: N/A

Iowa

There are 4,920 miles of groomed trails in Iowa. Registration Fee: $25 for two years.

Maine

There are 12,550 miles of groomed trails in Maine. Trails permits are required for non-residents. For more information, please contact the Maine Snowmobile Association via website at www.mesnow.com. Helmets are not required. Not all roads are open to snowmobilers. However, you may cross roads. Legally, road shoulders are not open to snowmobilers but road ditches are open behind plowed banks only. Speed limits are posted - reasonable & prudent. Non-residents must be registered in ME at $35/3 D, $55/10 D, $60 per season. Stickers must be displayed on both sides of sled. OUI Law - .08. Any person under 14 years old cannot drive across public roads and under 10 years of age cannot operate off own land. Registration Fee: $25 a year.

Massachusetts

There are approximately 500 miles of groomed trails in Massachusetts. A State registration decal is required to operate on all lands. Trail permits are required to ride trails on private lands - the operator may either obtain written landowner permission or join a club and the State Association. Operators must wear a helmet. Roads are not open to snowmobiles but can be traveled "adjacent to and parallel to" for a reasonable distance to a connecting trail. There are no posted speed limits. All snowmobiles must be registered with the State - there is no reciprocity with other states. Operators must be over 14 years of age to operate, between the ages of 12 and 14 they can operate with adult supervision. Registration Fee: is $20 per season for non residents, $30.00 for two seasons for residents. There are no safety course requirements for operating. For more information or to obtain a copy of the regulations contact Mass Environmental Police Central Headquarters, 617-727-3905. For Club information contact the Snowmobile Association of Mass, 413-369-8092 or visit our website www.snowassocma.com

Michigan

There are 6,000 miles of groomed trails in Michigan. Trail permits are required for all snowmobilers at $20 per season. For more information, please contact the Chamber of Commerce or the Michigan Snowmobile Association at 1-616-361-2285. Helmets are required for everyone. Roads in the state are open for snowmobilers in some Counties. Riding road shoulders and road ditches is allowed in some Counties only. Speed limits are (1) Safe and Reasonable, (2) posted on any road, (3) just fast enough to maintain forward motion when within 100 feet of any building or fisherman. Registration Fee: $22 for three years.

Minnesota

There are 18,000 miles of groomed trails in Minnesota. Trail permits are required for out of state snowmobilers at $16 per season. To order by credit card contact the MN DNR at 1-800-285-2000. Helmets must be worn by everyone up to 18 years old. Roads and road shoulders are not open for snowmobiles. Road ditches can be ridden in but travel must be with the flow of traffic after dark unless on a signed trail. Maximum speed limit is 50 mph. No metal traction devices are allowed on blacktop trails unless specifically signed to allow them. A $13 metal traction user fee is required for Minnesota residents only. Any Minnesota resident snowmobile rider born after 12/31/79 must possess a snowmobile safety certificate. For out of state riders, safety training requirements for their state prevail. For more information contact the DNR at 1-888-MINNDNR.

Montana

There are 3,772 miles of groomed trails in Montana. Trail permits are not required. Helmets are not required. Roads are open to snowmobilers only if groomed or not open to travel by wheeled vehicles. Road shoulders and road ditches are open for ride. No posted speed limits. Snowmobiles must be registered in home state. Registration Fee: $22.50 a year.

Nebraska

Nebraska has 100 miles of groomed trails. Trail permits are not required. Snowmobiles do not need to be insured. Helmets are mandatory for everyone. County Roads only are open to ride. Same applies for road shoulders and ditches. No specified speed limit. Registration Fee: $17.50 for 2 years.

New Hampshire

There are 6,800 miles of groomed trails in New Hampshire. Trails permits are not required but registration is. Registration is available through the Department of Fish and Game at 603-271-3129. Helmets are required for operators and passengers under the age of 17. Only certain roads and/or portions are open when applied for by local club or the Bureau of Trails. When they are open, they are posted. Otherwise all public ways are closed. Same rule applies for open road shoulders and ditches, still within the right-of-way. Speed limit is 45 mph unless otherwise posted. 10 mph when within 150 feet of any fisherman, their shanty or fishing hole. Also, speed that is reasonable and prudent for conditions then existing. Black Lake in Pittsburg has a 35 mph night time speed limit. Registration Fee: NH Resident $47.00 - Non-resident $62.00.

New York

There are 15,000 miles of groomed trails in New York. No trail permit required for out of state snowmobilers. Snowmobiles must be insured on roads. Helmets required for everyone. Some roads and road shoulders are open to snowmobiles. Road ditches are not. There are no posted speed limits. All snowmobiles must be registered in New York. Registration Fee: $15 Resident - $25 Non-resident

North Datoka

There are 2,000 miles of groomed trails in North Dakota. Trail permits are not required for out of state snowmobilers. Snowmobiles must be insured with minimum liability on any state trail. Helmets are required for anyone under the age of 18 years. Roads and road shoulders are not open to snowmobiles, however road ditches are. Speed limits the same as posted for that road if you are in a ditch. Trail speed limits are safe and prudent. Registration Fee: $20 for 2 years.

Ohio

There are 146 of groomed trails in Ohio. Trail permits are not required for out of state snowmobilers. Helmets are required for everyone. Roads are open to snowmobiles if decided by local authorities only. Same rule apples for riding road shoulders. Road ditches are not open. There is no posted speed limit. Registration Fee: $5 for three years.

Oregon

There are 6,200 miles of groomed trails in Oregon. Registration Fee: $10 for two years.

Pennsylvania

There are 2,000 miles of groomed trails in Pennsylvania. Trail permits are not required for out of state snowmobilers. Any state that honors PA registration in their state will have their registration honored in PA. Liability Insurance is mandatory for all snowmobiles. Helmets must be worn by everyone. Roads in the state are not opened unless indicated they are a joint use. They are mainly Township roads in sparsely populated areas. Same rule applies to road shoulders. You may legally ride in ditches. Speed limits are what is posted for that road if it is a joint use road. Youths between the ages of 10 and 16 must have a Safety Course and must carry the Certificate with them at all times showing they passed. Registration Fee: $20 for two years.

South Dakota

There are 1,052 miles of groomed trails in South Dakota. Trail permits are not required. Liability Insurance is mandatory for all snowmobiles. Helmets are not required. Roads that open are only roads that have not been plowed. Can legally ride in ditches and shoulders, only if there is no ditches. Speed limits are the same as the posted road limit - outside of road row's, no speed limit. Registration Fee: $20 for 2 years.

Utah

There are 1,038 miles of groomed trails in Utah. Registration Fee: $12.50 a year.

Vermont

There are 4,500 miles of groomed trails in Vermont. Trail permits are required and can be obtained through the Vermont Snowmobile Association for $30 plus local club membership for resident and $60 plus local club membership for non-reident. Snowmobilers from out of state must have certification that the after market exhaust meets the requirements that the manufacturer exhaust must meet. Helmets are not required. Roads are open to snowmobiles only when marked and signed for use. Road shoulders and ditches are open 3' off the plowed portion only. No speed limits. Snowmobiles must be registered in any state or province and must display a valid VT Trails Pass Decal. Trail Passes include VAST, County and Local Club Membership and is permission to operate on private land. Registration Fee: $16 resident - $22 Non-resident.

Washington

There are 3,500 miles of groomed trails in Washington. Trail permits are not required for out of state snowemobilers, however, a Sno-Park Permit may be needed to park in specific locations. Sno Park permits may be obtained by calling 360-902-8552. Helmets are not required. Roads, road shoulders and ditches are not open to snowmobiles. No person under age 12 shall operate a snowmobile. Persons between 12-16 must pass Snowmobile Safety Course to operate on any public road or highway. Registration Fee:

$32 a year.

Wisconsin

There are 25,000 miles of groomed snowmobile trails in Wisconsin. *Registration Fee: $20 for two years. A nighttime speed limit is now in effect* in Wisconsin. A 50 mph speed limit will be enforced on all trails in the state.

Wyoming

There are 2,500 miles of groomed trails in Wyoming. $15 Trail permits are required for out of state snowmobilers and can be obtained by calling 307-777-6560. Major Credit Cards Accepted. Helmets are not required. Roads are open to snowmobiles unless closed because of snow depth. Can legally ride road shoulders and ditches. No speed limits. Registration Fee: $15 a year.

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